A Prospective Observational Study of Abdominal Injury Management in Contemporary Military Operations

Damage Control Laparotomy Is Associated With High Survivability and Low Rates of Fecal Diversion

Iain M. Smith, MB, BChir, MSc, MRCSEd,†‡ Zine K. M. Beech, MB, BChir, MRCS,§ Jonathan B. Lundy, MD,|| and Douglas M. Bowley, MBBS, FRCS‡*

Objective: This study describes the cause, management, and outcomes of abdominal injury in a mature deployed military trauma system, with particular focus on damage control, hollow visceral injury (HVI), and stoma utilization.

Background: Damage control laparotomy (DCL) is established in military and civilian practice. However, optimal management of HVI during military DCL remains controversial.

Methods: We studied abdominal trauma managed over 5 months at the Joint Force Combat Support Hospital, Camp Bastion, Afghanistan (Role 3). Data included demographics, wounding mechanism, injuries sustained, prehospital times, location of first laparotomy (Role 3 or forward), use of DCL or definitive laparotomy, subsequent surgical details, resource utilization, complications, and mortality.

Results: Ninety-four of 636 trauma patients (15%) underwent laparotomy. Military injury mechanisms dominated [44 gunshot wounds (47%), 44 blast (47%), and 6 blunt trauma (6%)]. Seventy-two of 94 patients (77%) underwent DCL. Four patients were palliated. Seventy of 94 (74%) sustained HVI; 44 of 70 (63%) had colonic injury. Repair or resection with anastomosis was performed in 59 of 67 therapeutically managed HVI patients (88%). Six patients were managed with fecal diversion, and 6 patients were evacuated with discontinuous bowel. Anastomotic leaks occurred in 4 of 56 HVI patients (7%) with known outcomes. Median New Injury Severity Score for DCL patients was 29 (interquartile range: 18–41) versus 19.5 (interquartile range: 12–34) for patients undergoing definitive laparotomy ($P = 0.016$). Overall mortality was 15 of 94 (16%).

Conclusions: Damage control is now used routinely for battlefield abdominal trauma. In a well-practiced Combat Support Hospital, this strategy is associated with low mortality and infrequent fecal diversion.

Keywords: abdominal injury, anastomosis, battlefield injury, damage control laparotomy, war surgery

(*Ann Surg* 2015;261:765–773)

From the *202 (Midlands) Field Hospital, Birmingham, West Midlands, United Kingdom; †NIHR Surgical Reconstruction & Microbiology Research Centre, Birmingham, West Midlands, United Kingdom; ‡Royal Centre for Defence Medicine, Birmingham, West Midlands, United Kingdom; §Army Medical Directorate Support Unit; and ||US Army Institute of Surgical Research, Houston, TX.

Aspects of this work were presented orally at the 2013 Association of Trauma and Military Surgeons Congress, Glasgow, at the Ambroise Paré International Military Surgical Forum at International Surgical Week 2013, Helsinki, and by poster at the 2013 Association of Surgeons of Great Britain and Ireland Congress, Glasgow.

Disclosure: No funding was received in support of this work. J.L. is employed by the United States Army. I.S., Z.B., and D.B. are employed by the British Army. These data and the views expressed are the authors' own and do not necessarily reflect policy of the US Department of Defense or the UK's Ministry of Defence.

Reprint: LTC Douglas M. Bowley, RAMC, Royal Centre for Defence Medicine, Queen Elizabeth Hospital, Birmingham, United Kingdom. E-mail: doug.bowley@heartofengland.nhs.uk.

ISSN: 0003-4932/14/26104-0765
DOI: 10.1097/SLA.0000000000000657

The "aborted laparotomy" was described in 1983 as a technique to minimize operating time in patients after major civilian trauma,[1] thus averting the coagulopathic consequences of the "bloody vicious cycle."[2] Now termed "damage control" laparotomy (DCL),[3] this preceded the discovery that coagulopathy may arise early as a direct consequence of injury.[4] "Damage control resuscitation" (originally synonymous with "hemostatic resuscitation"[5–7]) has been redefined as a care bundle of which DCL is an established component.[8,9]

Although aspects of surgical practice in the Second World War may have represented application of damage control principles,[10,11] DCL, as currently understood, was initially considered unsuitable for military surgery due to the high associated mortality and the logistic implications of actively treating such massively wounded patients.[12] Although considered lifesaving, the evidence for DCL is limited. A recent Cochrane review failed to identify any literature more robust than case-control studies.[13] Nonetheless, it has become a common feature of deployed surgical practice.

The objective of this report was to describe the cause, initial management, and outcomes of abdominal injury managed at an established military hospital supporting counterinsurgency operations in Afghanistan. Of particular interest was the management of hollow visceral injury (HVI), specifically rates of repair, resection and reconstruction, and fecal diversion.

METHODS

We conducted a prospective observational study of all patients undergoing laparotomy for abdominal trauma at the Role 3 Joint Force Combat Support Hospital at Camp Bastion, Helmand Province, Afghanistan, from July to November 2012. This International Security Assistance Force (ISAF) facility is a multinational hospital providing care to both combatants and civilians injured during counterinsurgency operations. During the period of the study, surgical, anesthetic, and nursing staff included contingents from the United Kingdom, the United States, and the Republic of Estonia.

Data were collected on mechanism of wounding, injuries sustained, prehospital times, use of computed tomographic (CT) scanning, initial surgical management strategy, blood product administration in the first 24 hours from admission, details of subsequent laparotomies, intra-abdominal and extra-abdominal complications, time in the operating theatre, intensive care unit (ICU) and hospital lengths of stay, and mortality.

We defined a DCL as any operation in which the abdomen was intentionally left open at the end of the index procedure. Definitive laparotomy (DL) is defined by the completion of all intra-abdominal procedures and closure of abdominal fascia at the end of the primary procedure. We considered a therapeutic procedure to be one during which a therapeutic intra-abdominal intervention was performed. Surgical facilities were classified using NATO (North Atlantic Treaty Organization) definitions[14]:

Report Documentation Page

Form Approved
OMB No. 0704-0188

1. REPORT DATE	2. REPORT TYPE	3. DATES COVERED
01 APR 2015	**N/A**	**-**

4. TITLE AND SUBTITLE	5a. CONTRACT NUMBER
A Prospective Observational Study of Abdominal Injury Management in Contemporary Military Operations: Damage Control Laparotomy Is Associated With High Survivability and Low Rates of Fecal Diversion	5b. GRANT NUMBER
	5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S)	5d. PROJECT NUMBER
Smith I. M., Beech Z. K., Lundy J. B., Bowley D. M.,	5e. TASK NUMBER
	5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)	8. PERFORMING ORGANIZATION REPORT NUMBER
United States Army Institute of Surgica; Research, JBSA Fort Sam Houston, TX 78234	
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)	10. SPONSOR/MONITOR'S ACRONYM(S)
	11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release, distribution unlimited

13. SUPPLEMENTARY NOTES

14. ABSTRACT

15. SUBJECT TERMS

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT	b. ABSTRACT	c. THIS PAGE			
unclassified	**unclassified**	**unclassified**	**SAR**	**9**	

"Role 2" facilities are those "capable of triage, resuscitation, and damage control"; "Role 3" facilities have "access to diagnostic imaging and specialist surgery"; "Role 4" provides "definitive care ... [comprising] specialist surgical procedures, reconstruction, rehabilitation, and convalescence. This level of care is ... normally provided in the country of origin."

The US evacuation chain places Role 4 in Germany, with "Role 5" facilities in the continental United States.

Injury severity data were assigned by trained trauma nurse coordinators and were retrieved from the UK Joint Theatre Trauma Registry. The New Injury Severity Score (NISS)[15] was used in preference to the original Injury Severity Score (ISS),[16] as NISS has been shown to outperform ISS in various populations[17–19] and is considered a better reflection of the burden of military trauma in which multiple injuries to the same body region are common.[20]Using the military version of the Abbreviated Injury Scale,[21,22] a significant injury was one assigned a score of 3 or more. Major trauma was defined as an NISS of 16 or more.

Operating theatre time was included for any operating session in which a laparotomy was performed. This included time for the anesthetic procedure (which was performed at the operating table) and for any nonabdominal procedures performed in the same session as the time at which abdominal activity ended was not recorded. Data on operating theatre time and ICU stay relate only to activity at Role 3, as we were unable to capture the corresponding data for patients' stay at forward facilities or after evacuation to Role 4.

In cases in which it seemed that further resuscitation would be futile, consensus was achieved by discussion among the multidisciplinary team, led by the Deployed Medical Director, before the decision to cease intervention. Palliation was provided to such patients. These patients were excluded from analysis of complications. Patients transferred during the damage control sequence were also excluded from this analysis, as data concerning complications arising after evacuation (other than mortality) were not available to the authors. Complications relating to extremity injuries were not considered.

Statistical Analysis

Data are presented as median and interquartile range (IQR), unless otherwise specified. Ratio data were not normally distributed and were therefore compared using nonparametric methods. Ordinal data were compared with the Mann-Whitney *U* test. Categorical data were compared with the χ^2 or Fisher exact test as appropriate. *P* values of 0.05 or less were considered to indicate a significant difference. Analyses were performed with IBM SPSS Statistics for Windows, version 21.0 (IBM Corp, Armonk, NY).

Approvals

This study was approved by the Royal Centre for Defence Medicine, United Kingdom, as RCDM/Res/audit/1036/12/0265, and was authorized as a performance improvement project by the US Joint Combat Casualty Research Team.

RESULTS

Epidemiology and Injury Patterns

Ninety-four of 636 patients admitted because of trauma (15%) underwent laparotomy. The largest groups were Afghan Security Forces, consisting of army, national, and local police, and civilians. Demographics, mechanisms of injury, and measures of injury burden are shown in Table 1. The majority of injuries (94%) were caused by military wounding mechanisms.

Injury Burden

Injuries to intra-abdominal organs are shown in Table 2. Seventy-four of 94 patients (79%) had sustained extra-abdominal injuries, with the lower limbs most commonly involved (Fig. 1). Injury severity data were available for 88 of 94 patients (94%). Median NISS was 27 (IQR: 17–41). Fifty-nine of 88 patients (67%) had significant extra-abdominal injuries, and 16 of 88 patients (18%) had significant injuries in 2 or more extra-abdominal body regions (Table 1).

Retrieval and Initial Management of Casualties

Seventy-five of 94 patients (80%) were admitted directly to Role 3; time of injury was known for 53 of 75 patients (71%). Among these patients, median prehospital time was 54 minutes (IQR: 40–95 minutes). The initial management of casualties is summarized in Table 3. Sixty-five of 94 patients (69%) underwent CT scanning before laparotomy. The median time from arrival to theatre for patients managed without an admission CT scan was 14 minutes (IQR: 10–23 minutes) versus 55 minutes (IQR: 42–70 minutes) for those who underwent a CT scan ($P < 0.001$).

TABLE 1. Demographics of Patients Undergoing Laparotomy (N = 94)

Demographic	
Age,* yr	25 (21–28)
Affiliation	
ASF	43 (46)
Afghan civilian	25 (27)
ISAF personnel	13 (14)
Captured persons	6 (6)
Coalition civilian	1 (1)
Not recorded	6 (6)
Mechanism of injury	
Gunshot	44 (47)
Explosion	44 (47)
Blunt	6 (6)
NISS	27 (17–41)
Major trauma (NISS ≥16)†	71 (81)
Extra-abdominal injury present	74 (79)
Significant abdominal injury‡	58 (70)
Significant extra-abdominal injury†	59 (67)
≥2 extra-abdominal regions with significant injury†	16 (18)

All data shown as n (%) or median (IQR), unless otherwise stated.
*For 77 patients for whom data were available.
†For 88 patients for whom injury severity data were available.
‡For 83 patients for whom abdominal injury severity data were available.
ASF indicates Afghan Security Forces.

TABLE 2. Incidence of Injured Intra-abdominal Organs

Stomach	9
Small bowel	43
Colon	44
Rectum	6
Liver	15
Spleen	10
Pancreas	3
Kidney	6
Mesenteric vessels	6
Iliac artery	1
Iliac vein	6

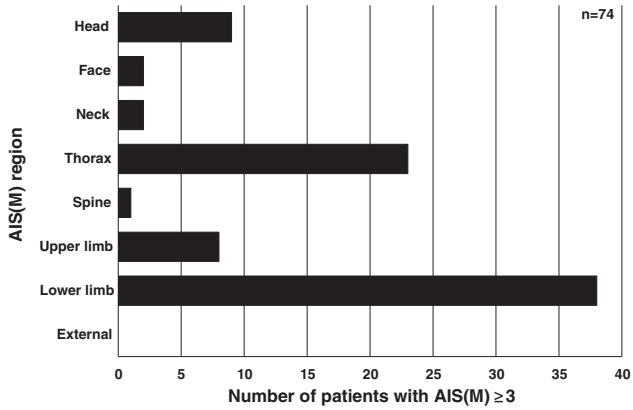

FIGURE 1. Distribution of significant extra-abdominal injuries. AIS(M) indicates military version of the Abbreviated Injury Scale.

TABLE 3. Retrieval and Initial Management of Casualties

Parameter	
Index laparotomy performed at Role 2	19 (20)
DCL performed at Role 2	18/19 (95)
Prehospital time,* min	54 (40–95)
Time from arrival to operating theatre at Role 3, min	45 (22–60)
CT scan performed before first Role 3 laparotomy	65 (69)
Management strategy at index procedure	
Palliation	4 (4)
Definitive index laparotomy	22 (23)
DCL and evacuation before definitive treatment	8 (9)
Definitive intra-abdominal management with laparostomy	9 (10)
DCL with delayed definitive treatment at Role 3	51 (54)
No. laparotomies	2 (1–3)

All data shown as n (%) or median (IQR), unless otherwise stated.
*For 54 patients admitted directly to Role 3.

Initial Surgical Management

Seventy-two of 94 patients (77%) underwent DCL. Eighteen of 19 patients (95%) admitted to Role 2 underwent DCL compared with 54 of 75 patients (72%) admitted directly to Role 3 ($P = 0.038$). All patients managed by DCL at Role 2 underwent a further laparotomy on arrival at Role 3. Fifteen of 18 patients (83%) underwent a second DCL at this time. In 3 of 18 cases (17%), intestinal continuity was restored on arrival at Role 3. Patients managed initially by DL and DCL are compared in Table 4. Compared with DL patients, the 72 patients managed with DCL were more severely injured and had a higher prevalence of significant abdominal injury, although the proportion defined as having sustained major trauma was not different. DCL patients had shorter intervals between arrival at Role 3 and transfer to the operating room and were less likely to undergo a CT scan before surgery. The damage control maneuvers used in the 69 DCL patients at Role 3 are shown in Table 5.

Eighty-four of 94 patients (89%) underwent a therapeutic laparotomy on arrival at Role 3. Four patients were palliated. Three patients had undergone DCL at Role 2 and required no immediate intervention at laparotomy on arrival at Role 3. Two of 3 patients received additional interventions during the next laparotomy, at which time all 3 achieved closure. Three of 94 patients (3%) admitted directly to Role 3 underwent nontherapeutic laparotomies and achieved closure at the index operation. Medial visceral rotation was performed in 2 of these to exclude visceral injury. The third had a retroperitoneal hematoma, thought to be due to a retroperitoneal bladder rupture (which was managed conservatively), but had no active intraperitoneal bleeding.

Resource Utilization

Consistent with the greater injury burden, transfusion requirements were significantly higher among patients who were managed with DCL than among those managed with DL (Table 4). There were no differences in blood product requirement between patients managed by DCL at Role 2 and Role 3 (data not shown). One DCL patient received 129 units or pools of blood products. DCL patients underwent a median of 2 laparotomies (range: 1–7), requiring a total of 453 hours of theatre time at Role 3 with a median of 4.88 hours (IQR: 3.37–7.75 hours). Many DCL patients were extubated at the end of their index procedure if physiologically suitable; the frequency of this practice was not recorded. Seventy-four of 94 patients (79%) were admitted to the ICU postoperatively; in 4 cases, this was for palliative care. For patients managed with therapeutic intent, median ICU and hospital stays at Role 3 were 2.2 days (range: 4.3 hours–23.0 days) and 6 days (3–14 days), respectively. Considering only those remaining at Role 3 for definitive care (n = 82), median theatre time was 5.53 hours (IQR: 3.81–8.62 hours), ICU stay was 2.4 days (IQR: 1.04–5.96 days), and hospital stay was 10.5 days (IQR: 5.5–19 days). Within this group, hospital stay was longer for patients who received an anastomosis [11 days (IQR: 6–20 days)] than those managed without [5.5 days (IQR: 3–11 days)] ($P = 0.006$).

Laparostomy Management

All open abdomens were managed with topical negative pressure dressings. Of the 60 DCL patients who remained in Role 3 for definitive care, 5 of 60 patients (8%) died before fascial closure. Delayed primary closure of fascia was performed in 47 of 60 patients (78%). Component separation was used to achieve fascial approximation in 3 of 60 patients (5%). A polyglactin mesh, which was allowed to granulate before split skin grafting, was placed in 2 of 60 patients (5%). Median time to fascial closure was 2 days (IQR: 1–2 days). In 3 of 60 patients (5%), the time and method of closure were not recorded. After delayed primary closure, 1 patient underwent a further laparotomy for anastomotic leak but was reclosed primarily. Four of 47 patients (9%) suffered full-thickness abdominal wound dehiscence. These were initially managed with topical negative pressure dressings. Fascial closure was achieved in 3 of 4 patients (75%) by insertion of a polyglactin mesh, and 1 was reclosed primarily.

Mortality

Mortality data are based on the last known status of patients. Casualty tracking processes provide robust data for ISAF personnel. Local nationals remained at Role 3 until ready for discharge home or to local facilities able to meet their current surgical, wound care, and nutritional needs. Overall known mortality was 15 of 94 (16%). Four of 15 patients (27%) were palliated at the primary laparotomy; 4 others (27%) died within 24 hours of admission. Of 8 patients transferred during the damage control sequence, 4 are known to have survived and 2 died. Two patients were transferred out of our casualty reporting chain, and their outcomes are unknown.

Management of Bowel Injury

Seventy of 94 patients (75%) sustained HVI. Its location and management are shown in Table 6. Three patients were palliated; primary or delayed repair or resection with anastomosis was performed in 59 of 67 patients (88%) managed with therapeutic intent. Six patients were managed with fecal diversion (1 also received a primary

TABLE 4. Comparison of Patients Managed With DCL Versus DL

Parameter	DL (n = 22)	DCL (n = 72)	*P*
Age,* yr	25.5 (21–30)	25 (20–28)	0.554
Affiliation			0.389
ASF	8	35	
Afghan civilian	6	19	
ISAF personnel	0	1	
Captured persons	1	5	
Coalition civilian	3	9	
Not recorded	4	3	
Mechanism of injury			0.274
Gunshot	10	34	
Explosion	9	35	
Blunt	3	3	
NISS	19.5 (12–34)	29 (18–41.5)	0.012
Major trauma (NISS ≥16)†	12 (67%)	59 (84%)	0.104
Significant abdominal injury‡	7 (39%)	46 (71%)	0.013
Extra-abdominal injury present	17 (77%)	57 (79%)	1.000
Significant extra-abdominal injury†	11 (61%)	47 (67%)	0.630
≥2 extra-abdominal regions with significant injury†	2 (11%)	14 (20%)	0.508
Prehospital time,§ min	40 (35–95)	57 (36–118)	0.161
Time from arrival to operating theatre, min	53 (42–143)	41 (18–59)	0.012
CT scan performed before operating theatre	19 (86%)	46 (64%)	0.046
No. laparotomies	1 (1–1)	2 (2–3)	<0.001
Blood product requirement in first 24 h			
Packed red blood cells	2 (0–4)	7 (3–13)	0.001
Plasma	1 (0–3)	7 (4–13)	<0.001
Platelet pools	0 (0–0)	1 (0–4)	0.001

All data shown as n (%) or median (IQR), unless indicated otherwise.
*For 77 patients for whom data were available.
†For 70 DCL and 18 DL patients for whom injury severity data were available.
‡For 65 DCL and 18 DL patients for whom abdominal injury severity data were available.
§For 54 patients admitted directly to Role 3.
ASF indicates Afghan Security Forces.

TABLE 5. Damage Control Maneuvers at Role 3

Maneuver	Times Used	% of DCL in Which Used
Aortic clamping	8	12
Iliac clamping	3	4
Abdominal packing (as definitive maneuver)	6	9
Splenectomy	7	10
Nephrectomy	1	1
Gastric repair	9	13
Discontinuous bowel (stapled or tied)	46	67
Extra-peritoneal pelvic packing	7	10
Pelvic external fixation	4	6
Extra-abdominal vascular shunt	3	4

repair and 1 received an anastomosis), and 6 patients were evacuated with discontinuous bowel (3 of whom had sutured repairs to additional non-destructive injuries). Thirty-eight small bowel anastomoses were created in 32 patients at Role 3. Fourteen ileocolic and 17 colocolic or colorectal anastomoses were created. Forty-four of 67 patients (66%) received 1 or more anastomoses (range: 1–5).

Six of 94 patients (6%) sustained rectal injuries. Fecal flow was interrupted at index laparotomy in all patients. One was transferred with discontinuous bowel, 5 of 6 were managed with defunctioning colostomy. Stomas were formed and the abdomen closed at the initial procedure in 3 of 5 cases. In the remaining 2 cases, colostomies were formed at subsequent procedures. In 2 of 3 patients, further procedures were required for wound dehiscence and for drainage of ischiorectal fossa and buttock sepsis (1 case each).

Complications

Complications were recorded for the 82 patients who remained at Role 3 for definitive management (Table 7). Of 56 such patients with an intestinal suture line or anastomosis, leakage occurred in 4 patients (7%). All leaks were from small bowel to small bowel anastomoses. Two of 4 patients with leaking anastomoses died (NISS = 52 and 75). One survivor developed multiple pelvic abscesses and an enterocutaneous fistula. The other patient had leakage from the proximal jejunum; this patient was managed by resection and refashioning of the anastomosis, laparostomy, and a further lavage before reclosure of the abdomen. One patient underwent a DL with the Hartmann procedure at Role 2 and was transferred to Role 3 for intensive care. This patient subsequently required multiple relaparotomies for wound dehiscence and colocutaneous separation with intra-abdominal retraction of the colostomy. One ISAF casualty, who had sustained thoracoabdominal injury and had undergone ileocolic resection, suffered an unexpected cardiac arrest in the ICU because of tension pneumothorax and underwent an emergency thoracotomy and nonanatomic lung resection. This patient was successfully repatriated to his home nation with discontinuous bowel but died from

TABLE 6. Location and Management of Injuries in Patients With HVI

	Patients, n (%)		
Injury location			
Isolated small bowel injury	20 (29)		
Isolated colonic injury	22 (31)		
Isolated rectal injury	5 (7)		
Combined small bowel and colonic injury	22 (31)		
Combined small bowel and rectal injury	1 (1)		
	All Patients (n = 70)	**Enteral Injury (n = 43)**	**Colonic Injury (n = 44)**
Palliative management	3 (4)	2 (5)	2 (5%)
Definitive index laparotomy	10 (14)	2 (5)	5 (11)
DL with primary repair		1 (2)	4 (9)
DL with primary anastomosis		1 (2)	1 (2)
DL with primary stoma construction	3 (4)*	0 (0)	0 (0)
DCL	57 (81)	39 (91)	37 (84)
DCL evacuated before definitive management	6 (9)	2 (5)	4 (9)
Primary repair with laparostomy	4 (6)	2 (5)	3 (7)
Primary anastomosis with laparostomy	1 (1)	1 (2)	
DCL with delayed primary repair (missed injury)	3 (4)	1 (2)	2 (5)
Colon repaired primarily at index procedure with discontinuous small bowel			2 (5)
DCL with delayed anastomosis at Role 3	41 (59)	32 (74)	25 (57)
Enteroenteric		26 (60)	
Ileocolic (for terminal ileal injury)		9 (20)†	
Ileocolic (for colonic injury)			9 (20)
Colocolic anastomosis			16 (36)
DCL with stoma construction	3 (4)‡	1 (2)§	1 (2)
Small bowel injury—management not recorded		1 (2)	
Suture line/anastomotic leak		4/41 (10)	0/38 (0)

*All stomas formed at index procedure were for rectal injury.
†Three patients received both ileocolic and enteroenteric anastomoses.
‡One patient had both a stoma and an enteroenteric anastomosis created at interval laparotomy.
§This ileostomy was performed after small bowel resection and was closed by ileocolic anastomosis before discharge.

TABLE 7. Complications in Patients Managed Definitively at Role 3

	DL, n (%) (n = 22)	DCL, n (%) (n = 60)	*P*
Intra-abdominal complications			
Unplanned return to operating theatre		10 (17)	0.092
Bleeding		6 (10)	
Evisceration past TNP dressing		4 (7)	
Extra-abdominal cause	2 (9)	1 (2)	
Failure of anastomosis or sutured repair	0/7 (0)	4/47 (9)	>0.999
Enterocutaneous fistula		2 (4)	
Pelvic abscess		2 (4)	
Surgical site infection		11 (18)	0.049
Fascial dehiscence	1 (5)	5 (8)	0.972
Prolonged postoperative ileus		5 (8)	0.400
Ischiorectal abscess	1 (5)		0.537
Necrotizing fasciitis		1 (2)	>0.999
Melena and gastric fistula at gastrostomy site		1 (2)	>0.999
Diarrhea (colitis, *Clostridium difficile*, unspecified)		3 (5)	0.772
Extra-abdominal complications			
Pneumonia	2 (9)	17 (25)	0.114
Clinically evident pulmonary embolus	1 (5)	7 (12)	0.710
Empyema		1 (2)	>0.999
Recurrent pneumothorax		1 (2)	>0.999
Bronchopleural fistula		1 (2)	>0.999
Pericarditis		1 (2)	>0.999
Endocarditis		1 (2)	>0.999
Critical illness polyneuropathy		1 (2)	>0.999
Urinary tract infection		1 (2)	>0.999

TNP indicates topical negative pressure.

respiratory failure 23 days after injury. A colostomy had been raised at relook laparotomy at Role 4.

DISCUSSION

Since the Vietnam War, abdominal injuries have accounted for 5% to 14% of injuries managed in military and independent humanitarian hospitals during time of conflict.[23,24] Traditionally, abdominal injury was managed definitively at the first procedure. Civilian experience with damage control in the 1990s prompted military surgeons to consider its potential for the management of battlefield trauma.[11,12,25] However, during the Gulf War of 1990–1991, no British or US surgeon performed a DCL.[26] The first recorded military DCL was in 1993 during the "Black Hawk Down" incident in Mogadishu, Somalia, when 2 patients underwent DCL to address major vascular, colonic, and additional abdominopelvic injuries; neither survived.[27] At the extremes of survivable injury, DCL casualties may consume vast quantities of resources (illustrated by the blood product requirements of patients managed by DCL in this series and previously[28]), which may be scarce in the deployed environment. Indeed, the International Committee of the Red Cross continues to caution that the "usefulness of damage control surgery when faced with mass casualties in a resource-poor setting is debatable."[29] At the beginning of this century, despite articles in military medical journals advocating damage control principles,[25] such concerns lead some US military surgeons to conclude that DCL would "be impractical for common use in a forward military unit during times of war."[12] However, others felt that DCL was already integrated in forward resuscitative surgery doctrine and argued that DCL in such situations should be understood as application of the concept of "minimum acceptable care."[11] A similar position was adopted by Australian Defence Forces, which, in 2004, stated that "damage control is uniquely suited to the ... military environment."[30] In the same year, DCL was formally incorporated into both British[31] and US[32] military surgical doctrine. In contrast to civilian DCS, in which all aspects of DCS will typically occur in one facility, military DCS may be complex, potentially involving treatment by clinicians from more than 1 nation and delivered at several levels of care in multiple facilities dispersed across 3 or more continents and during transport between these facilities.[33] Consequently, proponents of military DCL stressed the importance of rapid casualty evacuation by assets providing ICU-level in-transit care—a capability currently exemplified at Camp Bastion by the RAF Critical Care Air Support Teams[34] and the US Critical Care Air Transport Teams.[35]

Although it has been suggested that limiting surgery to "life-saving procedures only" during the Normandy landings constituted an application of damage control principles,[11] the earliest reports of successful contemporary military DCL came in quick succession from Iraq and Afghanistan, from forward surgical teams applying DCL in the very conditions for which some colleagues had previously deemed it inappropriate.[36–38] Subsequent series suggest an increasing prevalence of DCL in the management of battlefield abdominal trauma, from 22% in early reports[37] to 32% amongst British military casualties over a five year period to 2008,[39] 45% amongst US service personnel with colorectal injury evacuated to Germany [2010],[40] 51% of US personnel surviving to reach the USA [2013][28] and 77% in this series.

Abdominal Closure

We report a higher proportion of abdominal closure than previously noted after battlefield injury (49%).[41] This is likely due to non-ISAF personnel remaining in our facility until able to be discharged to the host nation health care system (in practice, after completion of all surgery) whereas the previous authors excluded abdominal closure achieved after 7 days or return to the United States. Of patients undergoing delayed primary closure of the abdomen, there was a relatively high rate of abdominal dehiscence (9%); this requires further study.

Management of Battlefield Colorectal Injury

The safety of primary repair of nondestructive colonic injury in physiologically stable civilian patients with minimal fecal contamination was established by randomized trial in 1979.[42] This was the first evidence-based challenge to the doctrine of mandatory proximal diversion of colonic wounds that arose from (arguably misunderstood[43]) experience in the Second World War.[44–46] Subsequently, meta-analysis of 705 patients from randomized trials has established that repair or resection with anastomosis as part of a definitive initial procedure has similar mortality to diversion with fewer infectious or wound complications despite more extensive injuries in those undergoing repair or anastomosis.[47] Nevertheless, a prospective observational study of 297 patients identified severe fecal contamination or transfusion of 4 or more units of blood as risk factors for abdominal complications after colonic injury requiring resection, irrespective of repair or diversion.[48] Patients with combat-related injury often have factors that would place them at a high risk, and recent studies have reported stoma formation in more than half of battlefield casualties with colonic injury.[28,40]

Delaying intestinal repair or anastomosis as part of a damage control sequence of operations is an appealing concept. An early report of delayed colonic anastomoses was that of 11 civilian patients who suffered similar complications as that of 21 patients with primary anastomoses despite a greater injury burden in the damage control group (mean ISS = 29 vs 17).[49] Although all-cause mortality was higher (45% vs 0%), no anastomotic failures occurred in the DCL group.

In a report from Colombia, 27 of 60 civilian patients with destructive colonic injuries (57 of whom were injured by gunshot) were managed by DCL.[50] Twenty-four of 27 patients were subsequently managed by anastomosis, of whom 2 had leakage and 1 died. Complications were compared between damage control with delayed anastomosis and definitive primary laparotomy but not between anastomosis and diversion in patients of the damage control group. Intra-abdominal abscesses treated by relaparotomy were identified in 31 of 60 patients—a far higher incidence than our patients or in a study of 133 military patients with battlefield colonic injury.[40]

Within the British military, a damage control operation is considered to be a procedure that "sacrifices the completeness of the immediate surgical repair in order to address the physiological consequences of the combined trauma (double hit) of injury and surgery,"[51] whereas the US military definition is "the rapid initial control of hemorrhage and contamination, temporary closure, resuscitation to normal physiology in the ICU, and subsequent re-exploration and definitive repair."[32] However, this is not universally applied. For example, 30 of 133 US casualties (23%) evacuated to Germany with colon injuries were reported as having undergone damage control surgery, defined as colon stapled in discontinuity. However, 60 (45%) arrived with laparostomies.[40] Accordingly, we would consider all 60 patients to have undergone DCL. Sixteen of these patients had stomas fashioned before evacuation, and 16 had undergone primary repair or anastomosis. Twenty patients had undergone anastomosis at the index procedure; however, 62% of patients with colon injury underwent fecal diversion, including 22 of 30 patients evacuated with discontinuous colon. A median of 2 laparotomies had been performed before evacuation, indicating widespread use of damage control. It is therefore possible that some patients categorized as "primary anastomosis" had undergone initial damage control and subsequent anastomosis before evacuation from theatre. Consequently, the true prevalence of damage control surgery in that cohort cannot be determined. Although British and US definitions of DCS are broadly

similar, we suggest that any consensus definition should reflect the current practice of simultaneous initial surgery and resuscitation, with further (definitive) surgery being deferred to a subsequent laparotomy.

Previous reports concerning recent military surgical results describe 21 anastomotic or suture line failures in 154 patients managed primarily (14% failure) compared with 5 leaks from 32 anastomoses (16%) created after DCL.[40,52–54] Although these numbers are too small for statistical analysis, the reported leak rate from colonic injury managed by DCL and delayed anastomosis has decreased stepwise from 17% (4/24)[53] and 10% (1/10)[54] to 0% (0/8)[40] and 0% (0/25) in the present series. With stoma formation rates of between 33%[53] and 62%,[40] this pattern might be said to illustrate improving case selection across the previous reports. Unfortunately, the largest study of colorectal injury during recent deployments reported neither the prevalence of DCS nor the anastomotic leak rate.[55] Mortality was higher among patients managed without fecal diversion (11% vs 4%) despite a higher injury burden in patients managed with fecal diversion. Injury severity was markedly higher among those who died (ISS = 34 vs 21), and the authors acknowledge the possibility that their results may be affected by survivor bias, in that the patients of the nondiverted group may include those who underwent initial damage control but did not survive to definitive management. Our results suggest that in the era of damage control resuscitation, colonic reanastomosis can safely be undertaken in selected patients at the second laparotomy; in essence, creating a semielective environment for restoration of intestinal continuity, with fecal diversion reserved for rectal injury or patients with ongoing hemodynamic compromise or massive injury burden.

In a recent study of a cohort of 925 civilian trauma patients with injury burdens comparable with our study,[56] 30% were managed by DCL. This was considered excessive by its authors, as 20% of their patients managed by DCL had none of the "classical" indications [T <95°F, pH <7.3, or INR (international normalized ratio) >1.5] for damage control on arrival in the ICU. However, patients managed by DCL had a higher ISS and greater physiological compromise, suggesting that surgeons recognized overall injury burden and physiological status and instituted DCL before the manifestation of the lethal triad. Such early recognition of the need for DCL is promoted in military trauma surgery,[57] and, although aggressive intraoperative damage control resuscitation may normalize physiology,[58] it is not known whether reversion from DCL to definitive surgery during the primary procedure is safe. Our study does not attempt to examine surgical decision making and did not capture admission physiology. It is possible that DCL was unnecessary in some of our patients. However, not only do we believe that a degree of intraoperative overtriage reflects safe decision making, but operational circumstances (such as multiple casualty situations) may also influence the required surgical approach.

Recent guidelines on the management of combat-related injuries recommend "strongly" that "early primary repair of complex or destructive colonic injuries should not be performed."[59] However, the time frame "early" was not defined. We agree that immediate anastomosis is usually inappropriate. Nonetheless, our data suggest that colonic injuries initially managed by DCS can be successfully managed by anastomosis later in the damage control sequence.

Cultural Significance of Stoma Avoidance

The majority of non-ISAF patients treated at the Camp Bastion Role 3 hospital are Muslim. In addition to the basic difficulties of accessing hygiene and stoma appliances, coping with a stoma in Afghanistan can be particularly challenging due to the impact of a stoma on the faith-based aspects of Islamic life.[60–62] When treating host nation patients, coalition surgeons should be mindful of this context. Strada and colleagues[63] have reported a cohort of 73 consecutive Afghan patients with colonic injury treated with a "zero-colostomy" policy. Only 4 of their patients (5.5%) died and 15% had complications. Our study adds to the evidence that ostomy may be safely avoided after colonic injury in this context.

Mortality

Many studies examining DCL exclude patients who died within 24 to 72 hours as having sustained unsurvivable injuries[41,48,50,64–68] or report only on coalition personnel who have survived to reach Role 4 or 5.[28,39–41,52,54] Eight of 15 deaths in our study occurred within 24 hours. Mortality among patients surviving more than 24 hours from arrival was 7 of 86 (8%).

Strengths and Weaknesses

In common with other articles arising from contemporary military operations, this study is limited to description of surgical activity and short-term outcomes. Trauma scoring systems correct for only some of the variability between patients. Similarly, individual variability between surgeons cannot be quantified, although collective predeployment training and collegial working will reduce this to some degree. Our data were collected over a shorter time than other comparable studies. This will minimize any confounding from changes in operational areas, deployment of Role 2 facilities, prehospital transport distances, and resuscitation practices. Whereas previous studies have concentrated on ISAF personnel, the largest group in our study was local nationals—a factor likely to pertain in future conflicts.

We could not report mortality by the conventional 30-day measure, as most patients were transferred out of our reporting system within that time. However, patients were only transferred when it was clinically appropriate and their needs could be met at the receiving facility. As with a previous study using this approach,[69] we would not expect a significant unknown mortality rate. Similarly, the median stay after anastomosis was appropriate for a leak to present and we therefore believe our data to be robust in this regard. We lack data on the further management and complications arising in ISAF personnel transferred during the damage control sequence, but as these were evacuated to higher levels of care, it is unlikely that their clinical course would have been worse than for patients described here.

Ultimately, the widespread acceptance of DCS in both civilian and military settings suggests that a randomized controlled study is unlikely to be ethical or achievable. This study reports perceived "best practice" after a decade's evolution of a military trauma system that has shown year-on-year improvement in survival.[70]

CONCLUSIONS

We report the first prospective observational study of abdominal injury management during modern conflict in a mature deployed trauma system centered on a purpose-built, multinational hospital, supported by robust logistics. The trauma system deployed in Helmand Province allows attending-delivered resuscitation to begin in the prehospital environment and continue through the emergency department, the damage control operation, and into the ICU. The damage control approach to military abdominal trauma is safe and allows restoration of intestinal continuity for injuries proximal to the rectum. Logistical planning for future military operations should consider damage control as the optimal approach to abdominal war injury.

ACKNOWLEDGMENTS

The Clinical Information Exploitation Team and Defence Statistics Health are thanked for collecting, collating and identifying the appropriate JTTR data for this paper.

Author contributions: D.B. and J.L. conceived the study, organized institutional review board approvals, and oversaw its conduct. D.B., I.S., and Z.B. collected data. I.S. analyzed the data and drafted the manuscript. D.B. and J.L. edited the manuscript. All authors agreed on the final submission.

REFERENCES

1. Stone HH, Strom PR, Mullins RJ. Management of the major coagulopathy with onset during laparotomy. *Ann Surg*. 1983;197:532–535.
2. Kashuk JL, Moore EE, Millikan JS, et al. Major abdominal vascular trauma—a unified approach. *J Trauma*. 1982;22:672–679.
3. Rotondo MF, Schwab CW, McGonigal MD, et al. "Damage control": an approach for improved survival in exsanguinating penetrating abdominal injury. *J Trauma*. 1993;35:375–383.
4. Brohi K, Singh J, Heron M, et al. Acute traumatic coagulopathy. *J Trauma*. 2003;54:1127–1130.
5. McMullin NR, Holcomb JB, Sondeen JL. Hemostatic resuscitation. In: Vincent JL, ed. *Yearbook of Intensive Care and Emergency Medicine 2006*. Berlin: Springer-Verlag; 2006:265–278.
6. Hess JR, Holcomb JB, Hoyt DB. Damage control resuscitation: the need for specific blood products to treat the coagulopathy of trauma. *Transfusion*. 2006;46:685–686.
7. Holcomb JB, Jenkins D, Rhee P, et al. Damage control resuscitation: directly addressing the early coagulopathy of trauma. *J Trauma Inj Infect Crit Care*. 2007;62:307–310.
8. Hodgetts TJ, Mahoney PF, Kirkman E. Damage control resuscitation. *J R Army Med Corps*. 2007;153:299–300.
9. Midwinter MJ, Woolley T. Resuscitation and coagulation in the severely injured trauma patient. *Philos Trans R Soc Lond B Biol Sci*. 2011;366:192–203.
10. Holcomb JB, Champion HR. Military damage control. *Arch Surg*. 2001;136:965–967.
11. Holcomb JB, Helling TS, Hirshberg A. Military, civilian, and rural application of the damage control philosophy. *Mil Med*. 2001;166:490–493.
12. Eiseman B, Moore EE, Meldrum DR, et al. Feasibility of damage control surgery in the management of military combat casualties. *Arch Surg*. 2000;135:1323–1327.
13. Cirocchi R, Montedori A, Farinella E, et al. Damage control surgery for abdominal trauma. *Cochrane Database Syst Rev.* 2013:CD007438. doi: http://dx.doi.org/10.1002/14651858.CD007438.pub3.
14. Senior NATO Logisticians' Conference. Medical support: role support. NATO Logistics Handbook Web site. 1997. Available at: http://www.nato.int/docu/logi-en/1997/lo-1610.htm. Accessed October 5, 2013.
15. Osler T, Baker SP, Long W. A modification of the injury severity score that both improves accuracy and simplifies scoring. *J Trauma*. 1997;43:922–925.
16. Baker SP, O'Neill B, Haddon W, Jr, et al. The injury severity score: a method for describing patients with multiple injuries and evaluating emergency care. *J Trauma*. 1974;14:187–196.
17. Balogh ZJ, Varga E, Tomka J, et al. The new injury severity score is a better predictor of extended hospitalization and intensive care unit admission than the injury severity score in patients with multiple orthopaedic injuries. *J Orthop Trauma*. 2003;17:508–512.
18. Sullivan T, Haider A, DiRusso SM, et al. Prediction of mortality in pediatric trauma patients: new injury severity score outperforms injury severity score in the severely injured. *J Trauma*. 2003;55:1083–1087.
19. Harwood PJ, Giannoudis PV, Probst C, et al. Which AIS based scoring system is the best predictor of outcome in orthopaedic blunt trauma patients? *J Trauma*. 2006;60:334–340.
20. Smith J, Hodgetts T, Mahoney P, et al. Trauma governance in the UK Defence Medical Services. *J R Army Med Corps*. 2007;153:239–242.
21. Champion HR. *Military Abbreviated Injury Scale 2005*. Silver Spring, MD: SimQuest LLC; 2007.
22. Champion HR, Holcomb JB, Lawnick MM, et al. Improved characterization of combat injury. *J Trauma*. 2010;68:1139–1150.
23. Champion HR, Bellamy RF, Roberts CP, et al. A profile of combat injury. *J Trauma*. 2003;54:S13–S19.
24. Leppaniemi AK. Abdominal war wounds—experiences from Red Cross field hospitals. *World J Surg*. 2005;29:S67–S71.
25. Bowley DM, Barker P, Boffard KD. Damage control surgery—concepts and practice. *J R Army Med Corps*. 2000;146:176–182.
26. Spalding TJ, Stewart MP, Tulloch DN, et al. Penetrating missile injuries in the Gulf War 1991. *Br J Surg*. 1991;78:1102–1104.
27. Mabry RL, Holcomb JB, Baker AM, et al. United States Army Rangers in Somalia: an analysis of combat casualties on an urban battlefield. *J Trauma*. 2000;49:515–528.
28. Bograd B, Rodriguez C, Amdur R, et al. Use of damage control and the open abdomen in combat. *Am Surg*. 2013;79:747–753.
29. Giannou C, Baldan M, Molde Å. Damage control: abbreviated laparotomy. In: *War Surgery: Working With Limited Resources in Armed Conflict and Other Situations of Violence*. Vol. 2. Geneva: International Committee of the Red Cross; 2013:442–445.
30. Neuhaus SJ, Bessell JR. Damage control laparotomy in the Australian military. *ANZ J Surg*. 2004;74:18–22.
31. Damage Control Surgery. In: Roberts P, ed. *The British Military Surgery Pocket Book*. AC12552. Camberley, Surrey, England: Department of Military Surgery, Army Medical Directorate; 2004:79–94.
32. Damage Control Surgery. In: Burris DG, Doughterty PJ, Elliot DC, et al. eds. *Emergency War Surgery*. 3rd ed. Washington, DC: Borden Institute; 2004:12.1–12.10.
33. Blackbourne LH. Combat damage control surgery. *Crit Care Med*. 2008;36:S304–S310.
34. Turner S, Ruth M, Tipping R. Critical Care Air Support Teams and deployed intensive care. *J R Army Med Corps*. 2009;155:171–174.
35. Beninati W, Meyer MT, Carter TE. The critical care air transport program. *Crit Care Med*. 2008;36:S370–S376.
36. Patel TH, Wenner KA, Price SA, et al. A U.S. Army Forward Surgical Team's experience in Operation Iraqi Freedom. *J Trauma*. 2004;57:201–207.
37. Chambers LW, Rhee P, Baker BC, et al. Initial experience of US Marine Corps forward resuscitative surgical system during Operation Iraqi Freedom. *Arch Surg*. 2005;140:26–32.
38. Beekley AC, Watts DM. Combat trauma experience with the United States Army 102nd Forward Surgical Team in Afghanistan. *Am J Surg*. 2004;187:652–654.
39. Fries CA, Penn-Barwell J, Tai NRM, et al. Management of intestinal injury in deployed UK hospitals. *J R Army Med Corps*. 2011;157:370–373.
40. Cho SD, Kiraly LN, Flaherty SF, et al. Management of colonic injuries in the combat theater. *Dis Colon Rectum*. 2010;53:728–734.
41. Sambasivan CN, Underwood SJ, Cho SD, et al. Comparison of abdominal damage control surgery in combat versus civilian trauma. *J Trauma*. 2010;69:S168–S174.
42. Stone HH, Fabian TC. Management of perforating colon trauma: randomization between primary closure and exteriorization. *Ann Surg*. 1979;190:430–436.
43. Edwards DP. The history of colonic surgery in war. *J R Army Med Corps*. 1999;145:107–108.
44. US War Department. *Notes on the Care of Battle Casualties*. Washington, DC: War Department; 1945. Technical Bulletin Medical 147.
45. Ogilvie WH. Abdominal wounds in the Western Desert. *Surg Gynecol Obstet*. 1944;78:225–238.
46. Carpenter RJ, Surgeon General of the United States Army. *Care of the Wounded in Theaters of Operation*. Washington, DC: Office of the Surgeon General of the United States Army; 1943. Circular Letter No. 178.
47. Nelson R, Singer M. Primary repair for penetrating colon injuries. *Cochrane Database Syst Rev*. 2003:CD002247.
48. Demetriades D, Murray JA, Chan L, et al. Penetrating colon injuries requiring resection: diversion or primary anastomosis? An AAST prospective multicenter study. *J Trauma.* 2001;50:765–775.
49. Miller PR, Chang MC, Hoth JJ, et al. Colonic resection in the setting of damage control laparotomy: is delayed anastomosis safe? *Am Surg*. 2007;73:606–609.
50. Ordonez CA, Pino LF, Badiel M, et al. Safety of performing a delayed anastomosis during damage control laparotomy in patients with destructive colon injuries. *J Trauma*. 2011;71:1512–1517.
51. Midwinter MJ. Damage control surgery in the era of damage control resuscitation. *J R Army Med Corps*. 2009;155:323–326.
52. Duncan JE, Corwin CH, Sweeney WB, et al. Management of colorectal injuries during Operation Iraqi Freedom: patterns of stoma usage. *J Trauma*. 2008;64:1043–1047.
53. Steele SR, Wolcott KE, Mullenix PS, et al. Colon and rectal injuries during Operation Iraqi Freedom: are there any changing trends in management or outcome? *Dis Colon Rectum*. 2007;50:870–877.

54. Vertrees A, Wakefield M, Pickett C, et al. Outcomes of primary repair and primary anastomosis in war-related colon injuries. *J Trauma*. 2009;66:1286–1291.
55. Glasgow SC, Steele SR, Duncan JE, et al. Epidemiology of modern battlefield colorectal trauma: a review of 977 coalition casualties. *J Trauma Acute Care Surg*. 2012;73:S503–S508.
56. Hatch QM, Osterhout LM, Podbielski J, et al. Impact of closure at the first take back: complication burden and potential overutilization of damage control laparotomy. *J Trauma*. 2011;71:1503–1511.
57. Midwinter M, Mercer S, Lambert A, et al. Making difficult decisions in major military trauma: a crew resource management perspective. *J R Army Med Corps*. 2011;157:S299–S304.
58. Morrison JJ, Ross JD, Poon H, et al. Intra-operative correction of acidosis, coagulopathy and hypothermia in combat casualties with severe haemorrhagic shock. *Anaesthesia*. 2013;68:846–850.
59. Martin GJ, Dunne JR, Cho JM, et al. Prevention of infections associated with combat-related thoracic and abdominal cavity injuries. *J Trauma*. 2011;71:S270–S281.
60. Kuzu MA, Topcu O, Ucar K, et al. Effect of sphincter-sacrificing surgery for rectal carcinoma on quality of life in Muslim patients. *Dis Colon Rectum*. 2002;45:1359–1366.
61. Karadag A, Baykara ZG. Colostomy irrigation: an important issue for Muslim individuals. *Asian Pacific J Cancer Prev*. 2009;10:1189–1190.
62. Iqbal F, Zaman S, Karandikar S, et al. Engaging with faith councils to develop stoma-specific *Fatawās*: a novel approach to the healthcare needs of Muslim colorectal patients [published online ahead of print September 3, 2013]. *J Relig Health*. Available at: http://dx.doi.org/10.1007/s10943-013-9772-4. Accessed October, 6, 2013.
63. Strada G, Raad L, Belloni G, et al. Large bowel perforations in war surgery: one-stage treatment in a field hospital. *Int J Colorectal Dis*. 1993;8:213–216.
64. Demetriades D, Murray JA, Chan LS, et al. Handsewn versus stapled anastomosis in penetrating colon injuries requiring resection: a multicenter study. *J Trauma*. 2002;52:117–121.
65. Kirkpatrick AW, Baxter KA, Simons RK, et al. Intra-abdominal complications after surgical repair of small bowel injuries: an international review. *J Trauma*. 2003;55:399–406.
66. Chavarria-Aguilar M, Cockerham WT, Barker DE, et al. Management of destructive bowel injury in the open abdomen. *J Trauma*. 2004;56:560–564.
67. Kashuk JL, Cothren CC, Moore EE, et al. Primary repair of civilian colon injuries is safe in the damage control scenario. *Surgery*. 2009;146:663–668.
68. Ott MM, Norris PR, Diaz JJ, et al. Colon anastomosis after damage control laparotomy: recommendations from 174 trauma colectomies. *J Trauma*. 2011;70:595–602.
69. Morrison JJ, Dubose JJ, Rasmussen TE, et al. Military application of tranexamic acid in trauma emergency resuscitation (MATTERs) study. *Arch Surg*. 2012;147:113–119.
70. Penn-Barwell JG, Roberts S, Bishop J, et al. Injuries and outcomes: UK military casualties from Iraq and Afghanistan 2003–2012. *Bone Joint J*. 2013;95-B:1.